INVESTIGATION OF THE FEASIBILITY OF AN ELECTROGASDYNAMIC PROBE FOR MEASUREMENTS OF MEAN AND RMS VELOCITIES

by

Richard Alan Christianson

United States
Naval Postgraduate School

THESIS

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Richard Alan Christianson
Lieutenant, United States Navy
B.S., Purdue University, 1964

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ABSTRACT

This study involves the investigation of the feasibility of an electrogasdynamic (EGD) probe to measure mean and turbulent velocities. The free stream velocity was 185 ft/sec and measurements were made in the wake of a circular cylinder 2 cm in diameter. Readings made with a hot-wire anemometer at the same location and in the same spectral range were used as the standard of comparison.

The initial data indicated that investigations should be restricted to the region from 2 mm to 10 mm aft of the injector nozzle along the center line. Spectral data for both the hot-wire and the EGD probe measurements were obtained with a frequency analyzer and photographed from an X-Y display.

The use of an EGD probe for measurements of mean and rms velocities may be feasible since the results indicate a definite correlation. The utility of the probe, however, is yet to be demonstrated since both the spatial and spectral comparisons with the hot-wire results show some lack of correspondence. The EGD unit proved to be considerably more rugged than the hot-wire probe.

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LIST OF ILLUSTRATIONS

LIST OF SYMBOLS

Symbol	
A	ampere
cm	centimeter
dc	direct current
^{o}F	degree Fahrenheit
EGD	electrogasdynamics
F	farad
ft	feet
ft/s	foot per second
ft^3/min	cubic feet per minute
Hz	hertz
h	height
I_c	corona current
I_G	collector current
I'_G	collector current per frequency band
I_N	needle current
in	inch
k	kilo
L	collector-to-ring distance along centerline
lbf	pound force
mm	milimeter
ms	milisecond

P_S	stagnation pressure
P_1	static pressure
psig	pound per square inch gage
q_o	dynamic pressure
rms	root-mean-square
T	percentage of rms velocity to free stream velocity
T'	percentage of rms velocity to free stream velocity per frequency band
U_∞	free stream velocity
V	volt
V_c	corona voltage
v	temporal mean velocity over an arbitrary point
vs	versus
w	weight
μ	micro
ρ	density
Ω	ohms

ACKNOWLEDGEMENT

The author wishes to express his gratitude for the encouragement and advice of Professor Oscar Biblarz, to Mr. Patrick Hickey for his many technical services, and to Mr. Warren Woodford for his skillful draftsmanship.

I. INTRODUCTION

Electrogasdynamics (EGD) is the study of the interaction of a non-neutral gas with an electric field. The charged particles within the gas are moved against the resistance of an electric field much as in the Van de Graaff generator, thus performing electrical work. In this case, however, the belt of the Van de Graaff generator is replaced by a moving gas stream. As pointed out by W. E. Bennett [1], a somewhat greater charge can be carried in a volume than on a surface (the Van de Graaff belt) and the charge transfer rate can be much higher with a moving fluid flow. Consequently, the EGD generator promises higher currents and greater efficiency. These theoretical possibilities do exist and are the subject of much research [1, 2, 3].

This thesis deals with a comparison of EGD probe readings of collector current with mean and rms velocities measured by a hot-wire anemometer in the turbulent wake of a circular cylinder. The study was undertaken to determine if there is any correlation between the two. This probe is a separate application from the EGD power generator [2]. The probe consists of a simple, rugged stainless steel rod used to collect the charged particles. These particles are highly coupled to the gas flow by virtue of their low mobility. The use of the turbulent wake of a cylinder is not restrictive. Presumably any high or moderate intensity turbulent

field can be handled, and the cylinder is one important application. As stated by Biblarz [2] a highly turbulent flow may yield favorable results in increasing the breakdown potential of the carrier gas so that it may improve the performance of the EGD probe.

There are three prominent features of the EGD probe which may make it more attractive as an anemometer than the hot wire. First, the EGD probe is considerably more rugged; therefore, very highly turbulent fields can be probed. Second, it may have a higher frequency response since charged particles (depending on size) can follow turbulent eddies better than the hot-wire system. Third, the probe tip comprises a small area which may yield a better or more symmetrical spatial resolution than the hot wire. But there are also disadvantages, the main ones being a requirement for a high-voltage source (which carries with it the ever enduring high-voltage safety precautions) and the need for a source of charged particles for optimum ion size to cover the desired frequency range.

This investigation is a continuation of a more comprehensive, long-term project being carried on by Professor Oscar Biblarz, Department of Aeronautics, Naval Postgraduate School, Monterey, California.

II. REVIEW OF PREVIOUS WORK

Numerous experimental studies involving the two-dimensional wake behind a circular cylinder have been performed. Those done by Schlicting and Reichardt [4] have proved to be standards in this field, hence the turbulent wake of the cylinder is reasonably well defined.

In the study of flow around bodies in air, it is useful for some purposes to deal with air as a perfect fluid owing to its low viscosity, since this leads to considerable mathematical simplification. However, perfect fluid theory does not apply to the experimentally observed boundary layer on the body, or to the flow separation and turbulent wake behind the body. Because of the complexity of turbulent fluctuations, a completely theoretical formulation of turbulent flow has not so far proved possible and investigations in this field are thus semi-empirical in nature. By the consideration of suitable time-averages of turbulent motion, however, a certain measure of correlation can be obtained between theoretical prediction and experimental observations.

Since the present investigation is concerned with the correlation between the EGD probe measurements and the standard data obtained with a hot-wire anemometer, the review will slant toward the EGD work and not expound on the more conventional aspects [5].

Hinze [6] states that P. Thomas was probably the first to apply an electric discharge for a technical purpose, namely, for designing a diaphragmless microphone for radio broadcasting. He further states that in 1934 F. C. Lindvall used the sensitivity of the glow-discharge potential to gas velocity for measuring turbulence. To measure turbulence, Lindvall used platinum electrodes of 1.5 mm diameter separated by a distance of about 0.1 to 0.2 mm. The total potential difference across the electrodes amounted to about 300 to 400 V.

Hinze mentions that there is a sensitive response to gas velocity. It is possible to obtain a potential difference of one volt for a difference in velocity of one meter per second. This is considerably more than is obtainable with the hot-wire anemometer, where the potential difference is of the order of 0.01 volt per meter per second. Lindvall considered this a very important advantage, because a less strong amplification is needed. Another important advantage is that effects corresponding to the thermal inertia of the hot-wire anemometer are very insignificant.

Other investigators of electrical-fluid interactions are F. D. Werner [7], K. J. Nygaard [8], and H. R. Velkoff [3] to name but a few. Werner investigated the possible use of the glow discharge as a means for measuring air flow characteristics, Nygaard looked at the anemometric characteristics of a wire-to-plane electrical discharge, and Velkoff carried on an extensive study

of electrostatic interactions with fluid flows. They concluded that the EGD system holds great promise as a velocity or mass flow measuring method.

The background for this present investigation is given in Ref. 2 and is demonstrated with early models by W. T. Ober [9] and D. W. Wallace [10].

Ober [9] describes a colloidal ion generator and states that an important consideration in the design of an effective EGD generator is the mobility of the charged particles which are to be forced out to the collector. Mobility is a measure of the velocity of a charged particle under the influence of an electric field. A high mobility indicates that it would be difficult to force the ions away from their migration path in the electric field (from the needle tip to the ring) and, therefore, a low mobility is desirable. The method used by Ober to produce these low mobility ions was by condensing saturated steam in a corona discharge by means of expansion through a nozzle.

III. TEST FACILITY

Air is supplied by a Carrier three-stage centrifugal compressor (Figure 1) with a 4000 ft^3/min maximum flow rate and a maximum pressure ratio of two. The test channel is preceded by a cooling bank and a main plenum, as shown in Figure 2. The cooling bank is used to keep the temperature of the air flow close to ambient and to hasten the temperature stabilization. The main plenum and the EGD flow channel plenum (Figure 3) serve to reduce the level of free stream turbulence in the test section.

A teflon cylinder two inches long with a two-centimeter diameter was placed in the test channel in a vertical position four inches prior to the outlet. This cylinder houses the aerosol injector [9]. The injector nozzle (Figure 4) was placed at the trailing edge of the cylinder. The EGD flow channel and injector (Figure 5) is described by Biblarz [2].

The EGD system wiring diagram is shown in Figure 6. A Sorensen High-Voltage dc Power Supply is used to provide corona power. The corona voltage is monitored with a Sensitive Research Electrostatic Voltmeter. Various Simpson microammeters are used to read the needle and corona current and a Keithley Pico-ammeter is used to measure the collector current. A 100 k Ω resistor is used to develop a voltage for an input to an oscilloscope. The input to a frequency analyzer is made through a 0.5 μF

capacitor, and the analyzer is grounded. It was found that shielding of the resistor is required along with absolute certainty of solid, smooth connections in all parts of the circuitry, especially a good ground circuit. As described by Wallace [10], three International Rectifier Corporation diodes are used to prevent any reverse current. For 10 μA of collector current the voltage drop across the diodes is about 21 V so that the frequency analyzer floats 21 V above ground, which means care must be taken to prevent damage to the equipment. Thus, a neon-bulb safety circuit was installed.

Preliminary work involved applying this resistor voltage drop to a Type 1A6 Differential Amplifier Plug-In Unit of a Type 551 Tektronix Dual-Beam Oscilloscope. Typical results of this are shown in Figure 7 where V_c was 2.2 kV, L was 8.1 cm and 1.02 cm to the right of the center line. I_G was 1.3 μA while I_N was 19 μA. The oscilloscope was set at 0.2 V/cm and 0.5 ms/cm. The figure shows the range of frequencies which are present in the EGD system.

A General Radio Company, Type 1921 Real-Time Analyzer was used as a frequency analyzer for both the hot-wire and EGD investigations. The 1921 analyzer consisted of a 1925 Multifilter and a 1926 Multichannel RMS Detector. The 1926 detector processes signals from the multifilter digitally. The outputs of the filters are sampled, the sample data converted to digital binary form,

and the rms level computed from this. Averaging is by true, linear integration, which is not only faster than running-average analog circuits (that may also miss transients) but it helps identify what events in time have contributed to the answer. The computed band levels are stored in a digital memory and are available at outputs simultaneously with analog data. Peterson and Gross [11] describe the specifications along with variations of use for this versatile piece of equipment. A Hewlett-Packard X-Y display was connected to the Real-Time Analyzer to get a rapid graphic output of the collector current. Figures 8 and 9 show some of this equipment. As stated, the analyzer indicates spectral rms values as measured by either the hot wire or the EGD probe.

Measurements of pressure, temperature, and humidity were made with conventional metering equipment.

The collector probe was a 0.125 in stainless steel rod with a smooth pointed tip. It is rugged and was easily constructed. It can be placed in any position of the flow and was mounted on an insulated traversal unit allowing vertical and horizontal movement for any axial position to within $\pm$ 0.5 millimeters.

A steam generator supplies steam to the cylinder through a heated line to prevent condensation of the steam while it is in the line. The cylinder acts as a reservoir and feeds steam to the nozzle.

IV. EXPERIMENTAL PROCEDURE

The first portion of this investigation consisted of determining the standard airflow properties of the wake behind a circular cylinder. All the tests were made at a Mach number below 0.3 and at atmospheric conditions. A constant temperature hot-wire anemometer, Security Associates, Model 200, with a 0.00015 in diameter tungsten wire in the probe was used to determine the velocity and turbulence in and around the wake as shown in Figure 10. When using the hot-wire anemometer, the symmetry of the cylinder was exploited and probes were made only from the center line to the right side outward. Various spot checks were made in other portions of the wake to validate this use of symmetry. Both overall rms-turbulence and individual band turbulence was obtained by a Balantine True RMS Voltmeter and the frequency analyzer respectively. To reduce breakage of the hot wires, the air flow was no higher than 185 ft/s as computed in Appendix A. Moreover, all the data were obtained at this speed. Both mean and turbulent velocities within the wake were read as a percentage of free stream velocity.

The second portion of this investigation consisted of taking the EGD system readings. Again the air flow was at 185 ft/s and the same locations were used for probing here as with the hot-wire anemometer. Charged particles were injected into an air stream

first by the use of a molecular ion device and later a corona-aerosol device. These particles were then collected by a small, rugged metallic probe at the desired position. The EGD interaction using molecular ions was too weak. The use of an aerosol flow consisting of charged water droplets in air increased the collector current. Steam at a pressure of 14 psig and 250°F was used through the injector; ambient temperature was 72°F. Preliminary work showed very little difference in the hot-wire anemometer readings with and without steam as long as the steam remained dry. But it was decided not to use the steam with the hot wire because of the uncertainty of interpreting results in the two-phase system. Instead, air at the same reservoir pressure as the steam was used (this matches the momenta of the two).

Prior to applying the high voltage, a visual check of the circuitry was performed along with a continuity check on the needle and ring of the injector. This corona unit was cleansed with freon for each run to reduce surface breakdown. Following each run, after high voltage shut down, all main connections were grounded with a grounding rod to insure against electrical shock.

The EGD system was connected as shown in Figure 6 and the readings were taken for comparison with the hot-wire anemometer data. Biblarz [2] discusses the principles of operation of this EGD system in some detail and notes that the collector probe retrieves the charges and causes a buildup of a potential between the collector

and ground, with the resulting current flow through the collector circuit representing the work done by the air flow, or the output of the EGD system. The EGD probe is basically a short-circuited EGD generator.

The frequency analyzer was set for four-second integrations from band 14 to band 43, 25 Hz to 20 kHz in one-third octave bands. Eight-second integrations were also used to compare the results of the same conditions to the four-second integrations. No discernible difference was detected. The analyzer results were portrayed on the X-Y Display and photographed.

V. DISCUSSION OF RESULTS

EGD probe readings of collector current and mean and rms velocities measured by a hot-wire anemometer were made to determine the spatial correlation of the three, and then spectral measurements were taken in regions of good correlation. The results of this investigation will be discussed from an analysis of Figures 10 through 28.

Figures 11 through 15 show the actual data of mean velocity, turbulence and collector current measured at the probe positions shown in Figure 10. The mean velocity is expressed as a ratio of mean velocity to free stream velocity (v/U_{∞}) while the turbulence (T) is expressed as a percentage of the rms velocity to free stream velocity. Figures 16 and 17 depict scattergrams of these data and were used to determine where the EGD collector current compares favorably with the hot-wire measurements. These results indicate an acceptable correlation of collector current and turbulence over a portion of the region investigated. This region is within a plane oriented with the flow, one cm on either side of the center line running from the nozzle to the exit of the test section. The mean velocity did not compare favorably, and near the center line there was somewhat of an inverse correlation. Further investigations were restricted to comparisons of collector current and turbulence along the center line. The highest collector currents occurred at

about two centimeters aft of the cylinder on the center line; this can probably be attributed to the characteristics of the charged aerosol. The scattergrams (Figures 16 and 17) show a somewhat regular pattern between the EGD collector current and both mean and overall rms velocities.

Figures 18 through 25 show the spectral data from both the hot-wire anemometer and the EGD probe at different positions behind the cylinder on the center line. These data were obtained from the frequency analyzer and photographed on the X-Y Display. The horizontal scale is a frequency scale running from 25 Hz to 20,000 Hz; the analyzer outputs in 30 discrete bands. The vertical scale is a voltage proportional to the rms value. Figure 18 shows the reference value and an internal calibration. The residual free-stream turbulence can be seen in the upper picture. Figure 19 shows the EGD probe reference without air flow. Note the absence of high frequencies in Figures 18 and 19. Figures 20 through 25 show measurements at three different locations behind the cylinder (4 mm, 5 mm and 7 mm). Zero is always the lower left-hand blip. First the hot-wire turbulence measurements were made with just the main air to establish a local reference, and then with both main and nozzle air. The nozzle air permits the simulation of the EGD probe flow field but without the steam. Subsequently, the EGD probe current readings were taken at the same location so that spectral comparisons could be made. The next task is to better

define the comparable features of these curves.

Figure 26 is a normalized curve of the hot-wire (nozzle and main air) and EGD results at L = 5 mm. This curve is typical of the data obtained. The bands corresponding to the vertical grid lines are identified there. A peak at twice the Strouhal frequency [4] of the cylinder can be seen here, as well as in all of the spectral data obtained. (The Strouhal number for this cylinder is 0.21.) Also in this figure, the hot-wire readings lie below the EGD probe at the low frequencies, but at the high frequencies they lie above. Figure 27 is a scattergram of the collector current per frequency band (I_G') and the turbulence per frequency band (T') for the same data as Figure 26. This graph shows the result that the collector current is a function of turbulence at the higher frequencies (1,250 - 10,000 Hz).

Figure 28 indicates the ratio of I_G'/T' vs frequency for all three spacings reported. Because of the small scatter of the data, the figure displays a definite functional dependence between I_G'/T' and frequency. A relative minimum lies close to twice the Strouhal frequency, but otherwise a smooth curve can be drawn through the points.

VI. CONCLUSIONS AND RECOMMENDATIONS

The use of an EGD probe for measurements of mean and rms velocities is feasible since the results of Figures 16, 17, 27 and 28 indicate a definite correlation. The utility of the probe, however, is yet to be demonstrated since both the spatial and spectral comparisons with the hot-wire results show some lack of correspondence.

As seen from Figures 18, 19 and 26 the high frequencies are contributed by a range of vortices shedding off the cylinder, centered about the Strouhal frequency. The reason for seeing twice the Strouhal value is because readings were taken along the center line of the cylinder. This octave above the Strouhal frequency shows as a definite peak in all the data, although the EGD probe readings indicate a slightly higher value.

The conjuncture that the EGD probe may have a higher frequency response than the hot-wire anemometer is not validated by Figure 28. This may be due to the large droplet size issuing from the injector (this situation was brought about by the necessity to run the steam injector at its highest wetness in order to maximize the collector current). This fact may also explain the low frequency discrepancy, since relatively large droplets would enhance the low frequency spectrum. It is recommended, therefore, that more tests be run with dryer steam to check out the frequency dependence of the charged aerosol. This hopefully would raise the high frequency

end in Figure 28. In this figure, a horizontal band is desired but not necessary since a definite correlation can be expressed algebraically and used to interpret the EGD probe data.

The EGD probe was indeed more rugged in that it did not break, whereas at least 20 hot wires did, even though tests were at the low velocity of 185 ft/s. The particular hot-wire anemometer used gave the greatest problem by drifting, so care must be exercised here. Since both the same traversal unit and probe mount were used for the EGD and hot wire systems, it is believed that the frequencies introduced from probe vibrations are the same.

The spatial resolution in these experiments was undetermined, and it is hoped that this item can be looked into in future work.

A possible way to improve results may be to increase the amount of collector current while retaining the ability to change the wetness of the vapor. This might be accomplished through a more carefully constructed injector unit in which the spacing between needle and ring can be varied. Obviously, more work is needed to optimize the injected particle sizes for a given frequency range.

A practical EGD probe would require the development of an injector which is small and can be traversed with the collector, perhaps with a fixed spring. This would permit the probing of more arbitrary flow fields.

APPENDIX A

Determination of Free Stream Velocity

A pitot-static tube located in the front of the test channel was utilized to obtain the readings for this determination and applied as described by Pao [12].

$$q_o = P_S - P_1 = 1/2 \rho v^2 = wh$$

$$q_o = \frac{(62.4 \text{ lbf/ft}^3) \times (h(cm)cm)}{(2.54 \text{ cm/in}) \times (12 \text{ in/ft})} = 2.045 \text{ h(cm) lbf/ft}^2$$

$$U_\infty = (2q_o/\rho)^{1/2} = \frac{(2 \times 2.045 \text{ h(cm)lbf/ft}^2 \times 1 \text{ slug-ft})^{1/2}}{(0.002378 \text{ slug/ft}^3 \times \text{ lbf-s}^2)^{1/2}}$$

$$U_\infty = 41.5(h(cm))^{1/2} \text{ ft/s}$$

$$U_\infty (h = 20 \text{ cm}) = 185 \text{ ft/s}$$

APPENDIX B

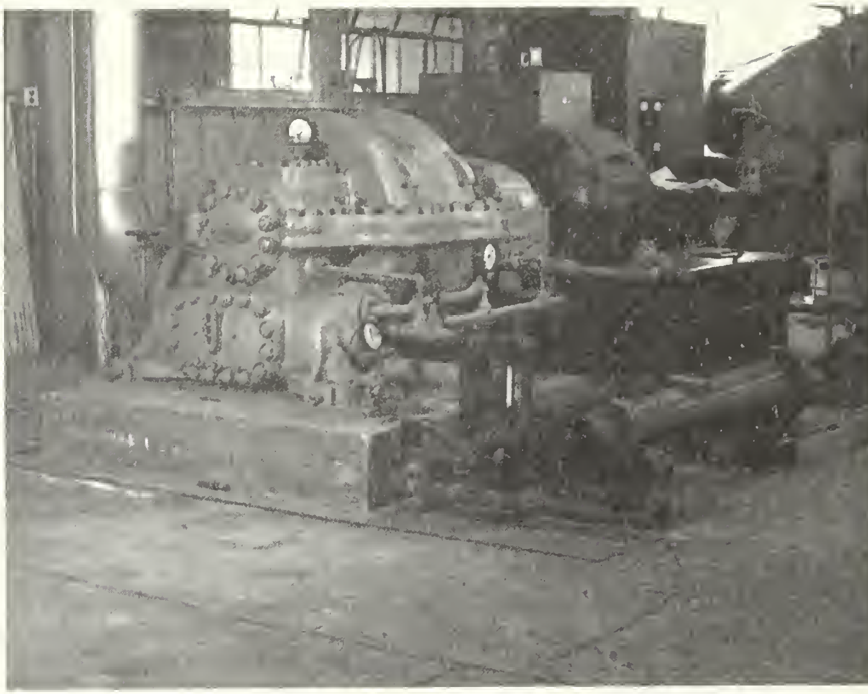


FIGURE I. AIR SUPPLY COMPRESSOR

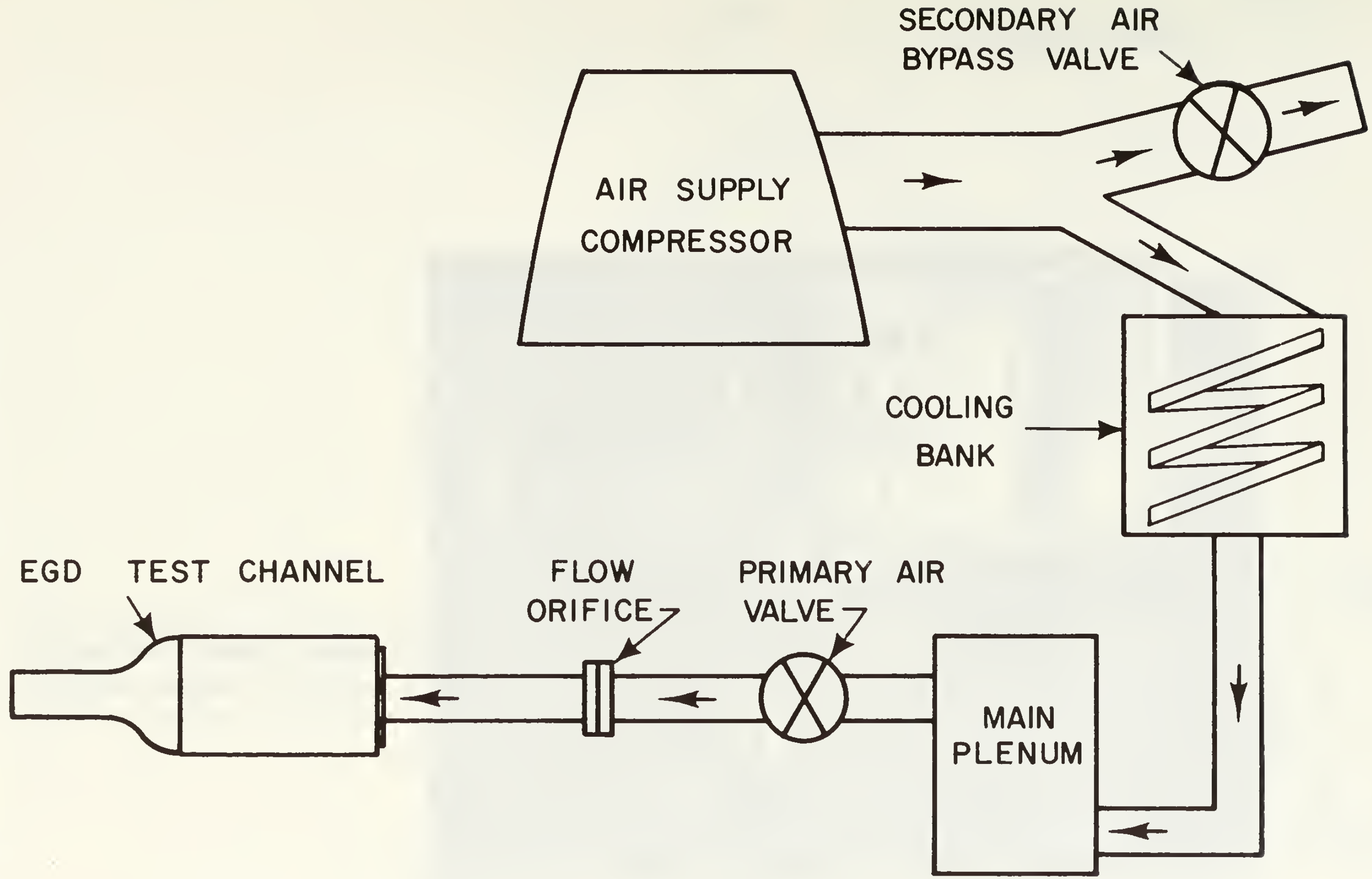


FIGURE 2. EGD SYSTEM FLOW CHART

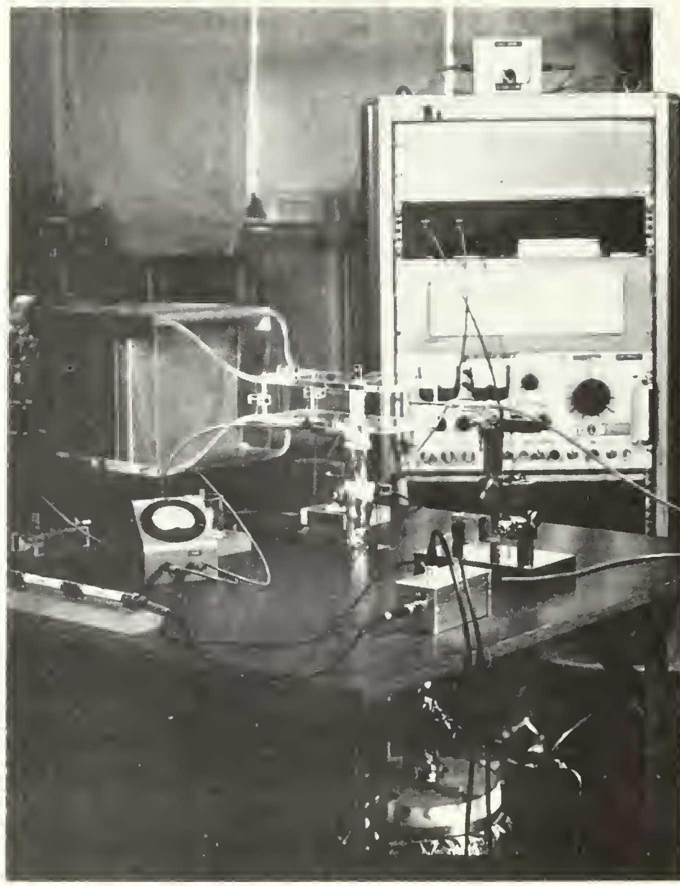


FIGURE 3. EGD TEST SETUP

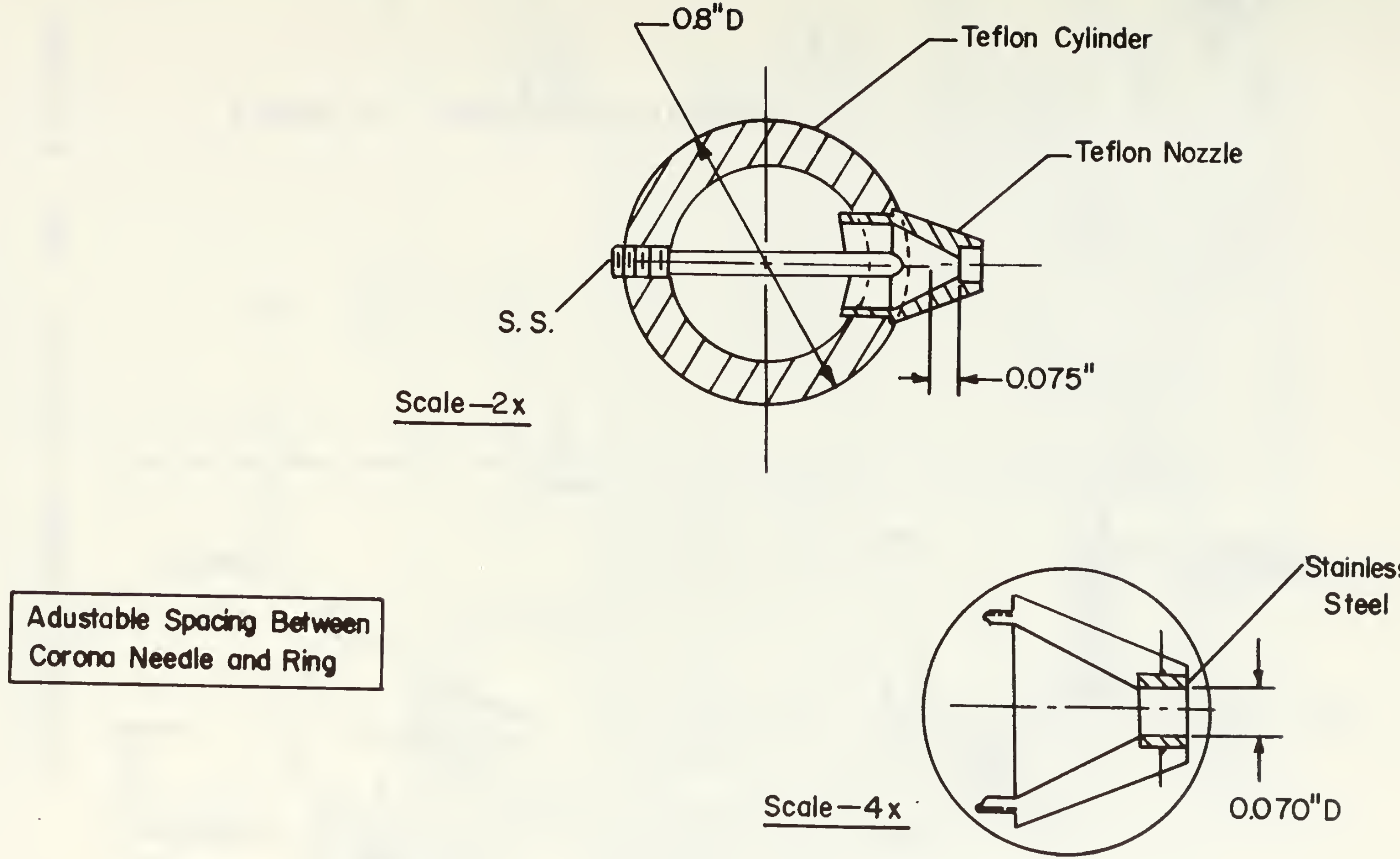


FIGURE 4. AEROSOL INJECTOR

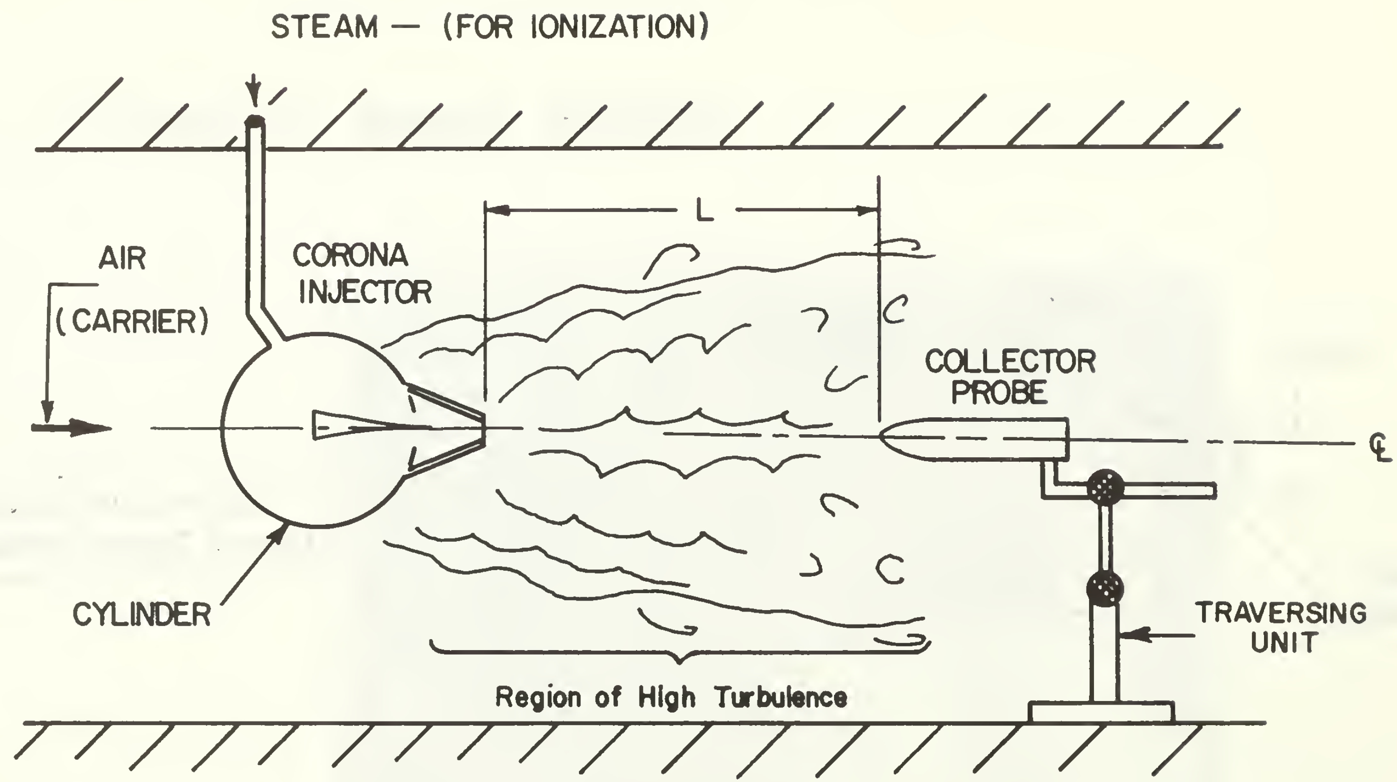


FIGURE 5. EGD FLOW DIAGRAM

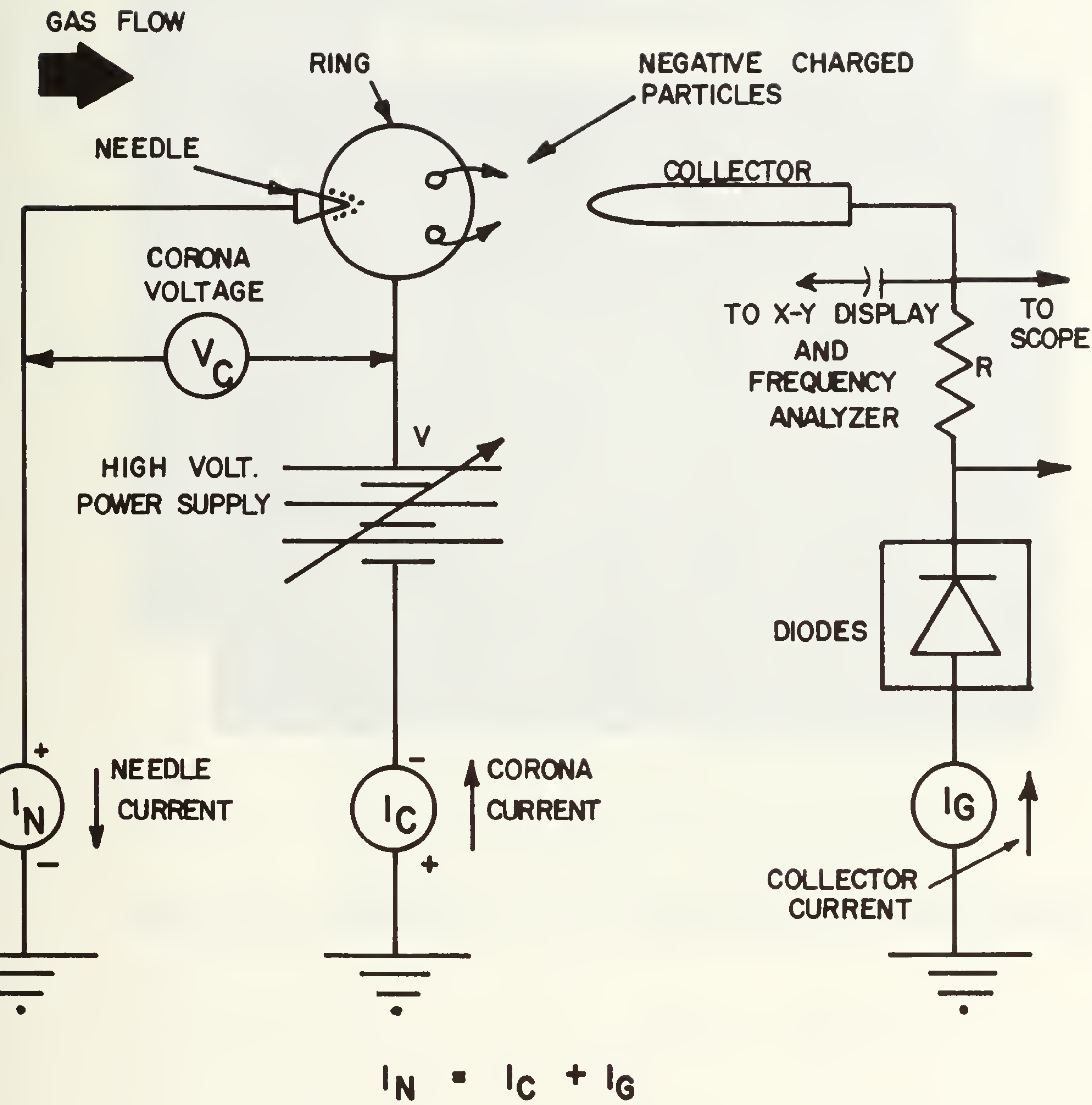
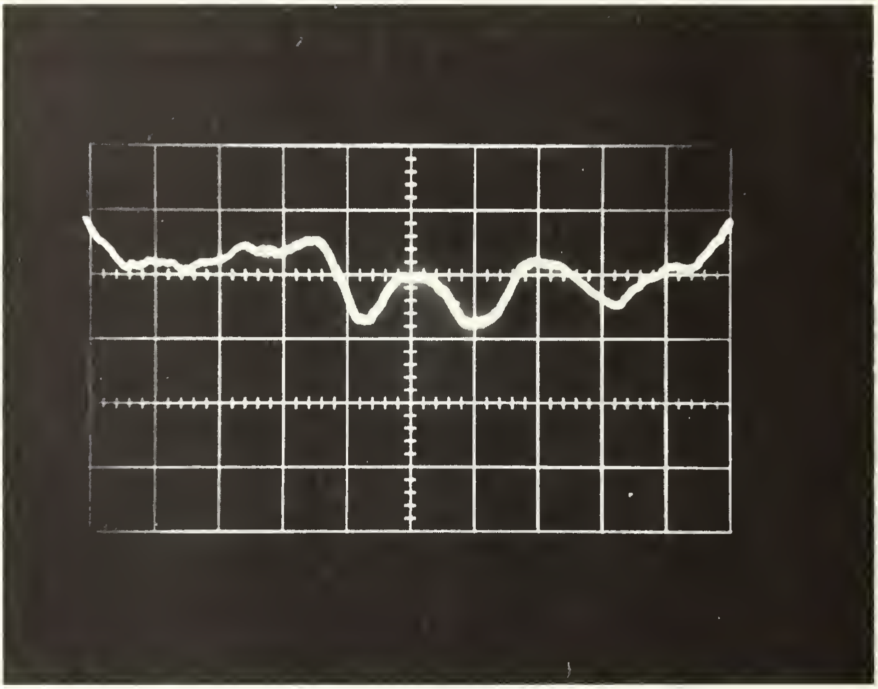


FIGURE 6. EGD SYSTEM WIRING DIAGRAM



HORIZONTAL : 0.5 ms / cm VERTICAL : 0.2 V /cm

FIGURE 7. A.C. COLLECTOR CURRENT OSCILOSCOPE PATTERN.

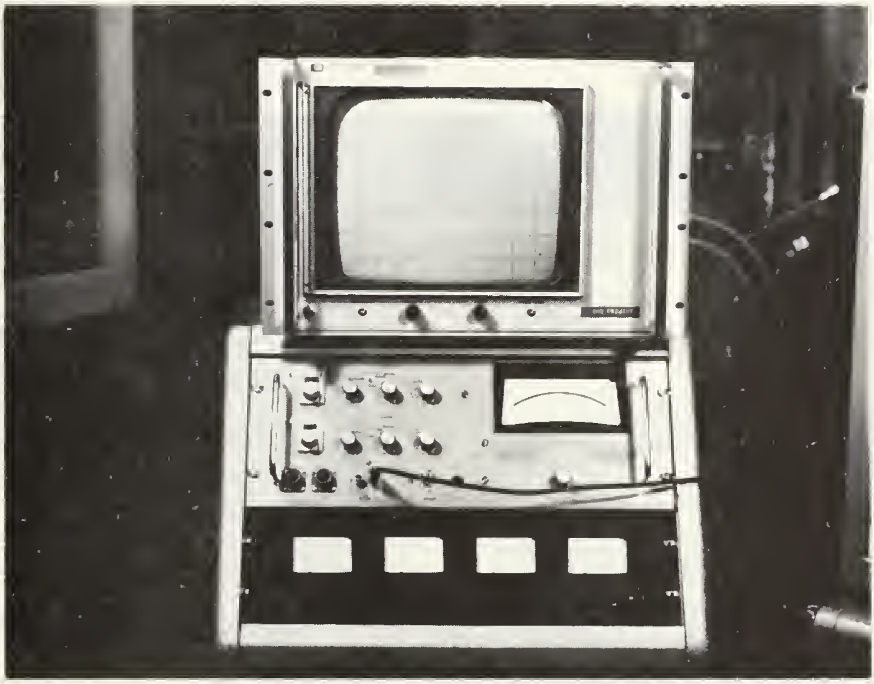


FIGURE 8. X-Y DISPLAY AND HOT-WIRE ANEMOMETER

FIGURE 9. ELECTROSTATIC VOLTMETER (TOP)
PICOAMMETER (CENTER)
FREQUENCY ANALYZER (BOTTOM)

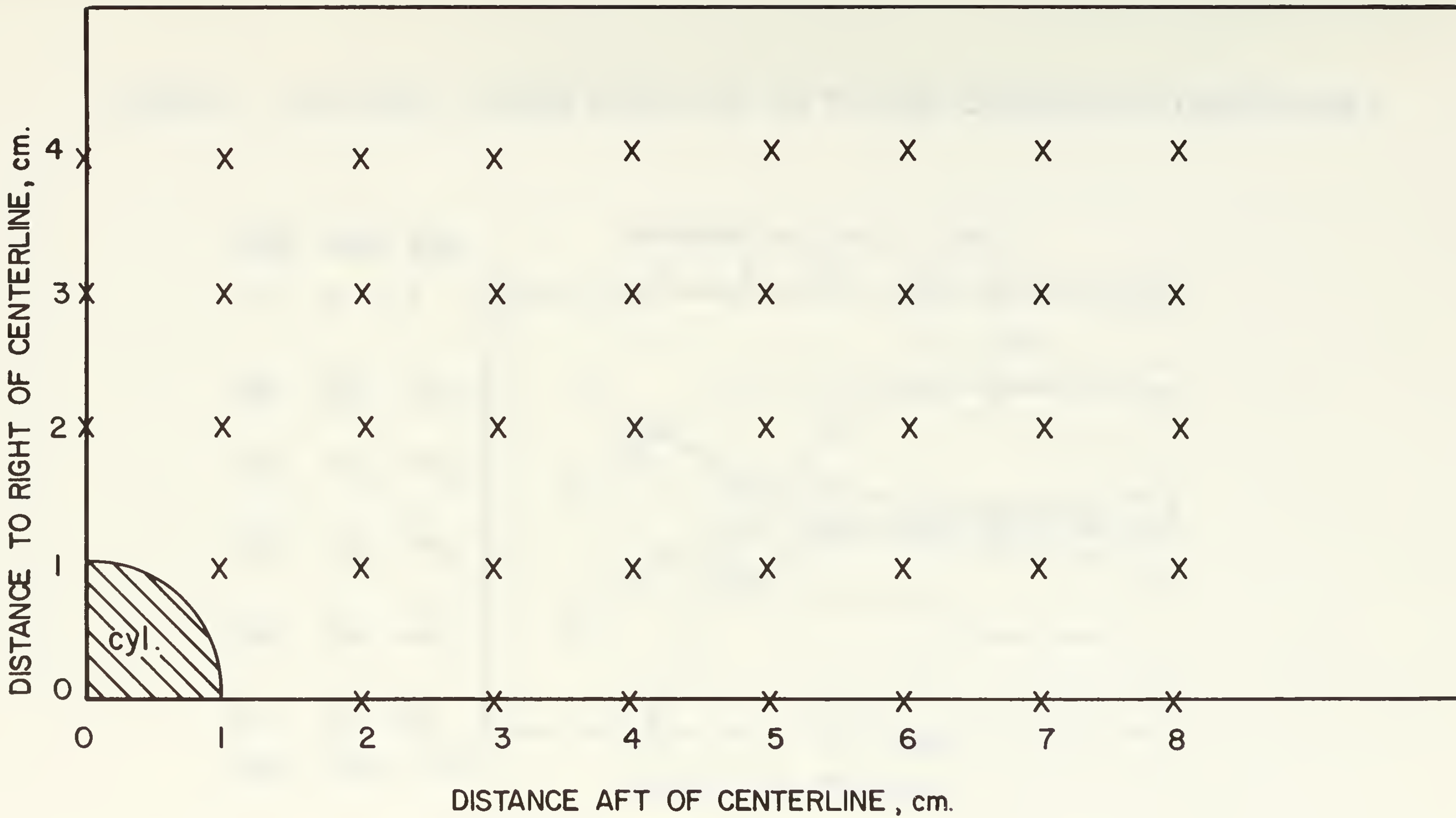


FIGURE 10. DATA POINT PROBE POSITIONS

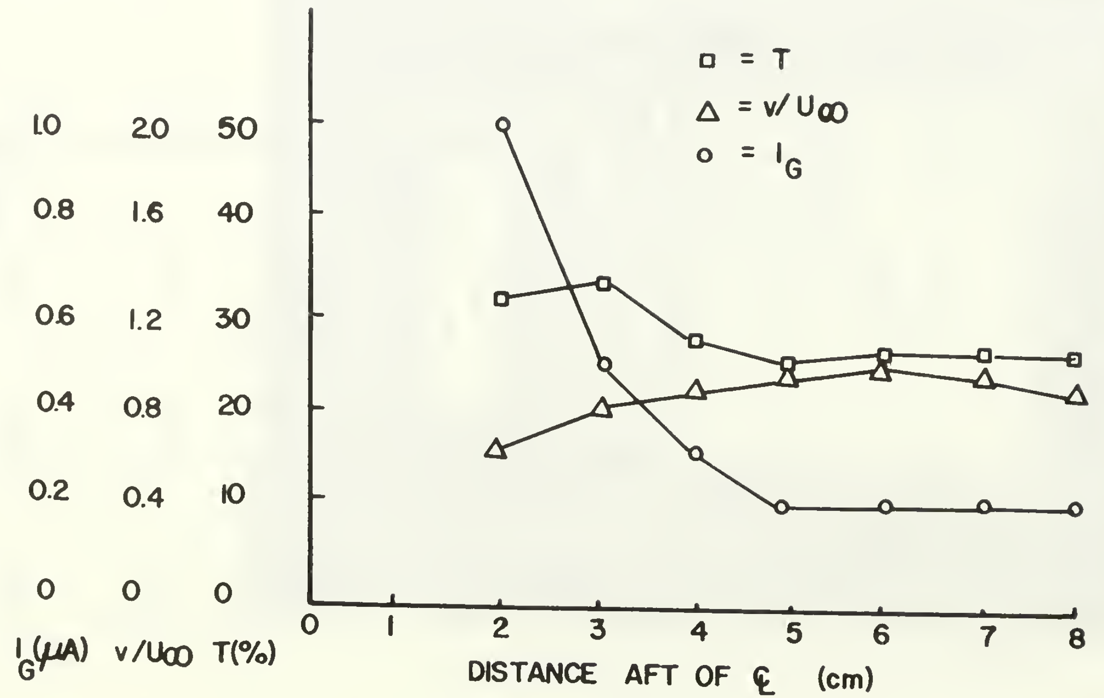


FIGURE 11. VELOCITY, TURBULENCE AND COLLECTOR CURRENT (ON CENTERLINE)

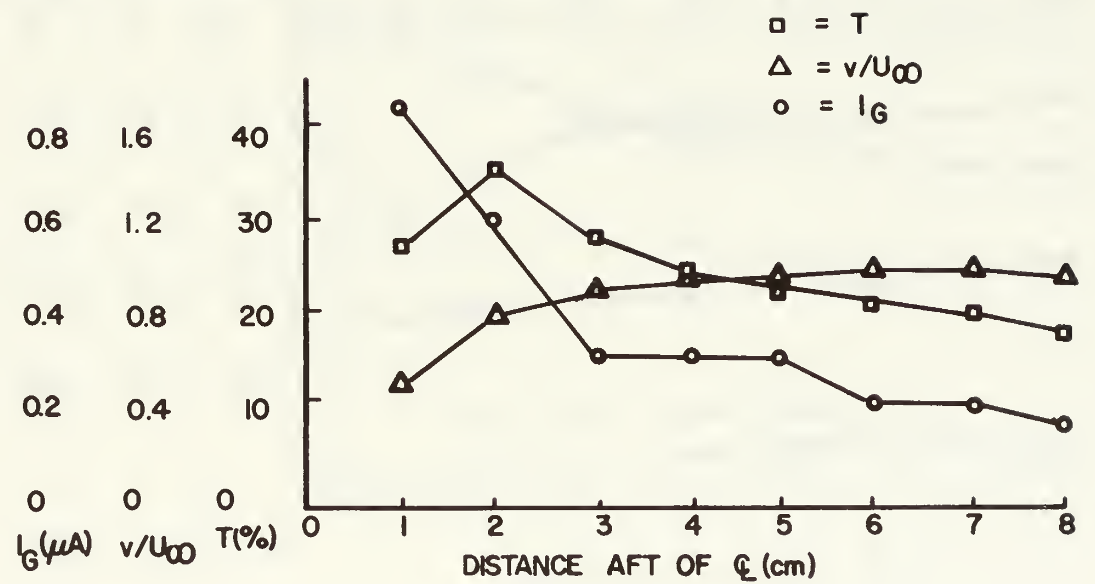


FIGURE 12 VELOCITY, TURBULENCE AND COLLECTOR CURRENT (ONE CM. TO RIGHT OF CENTER LINE)

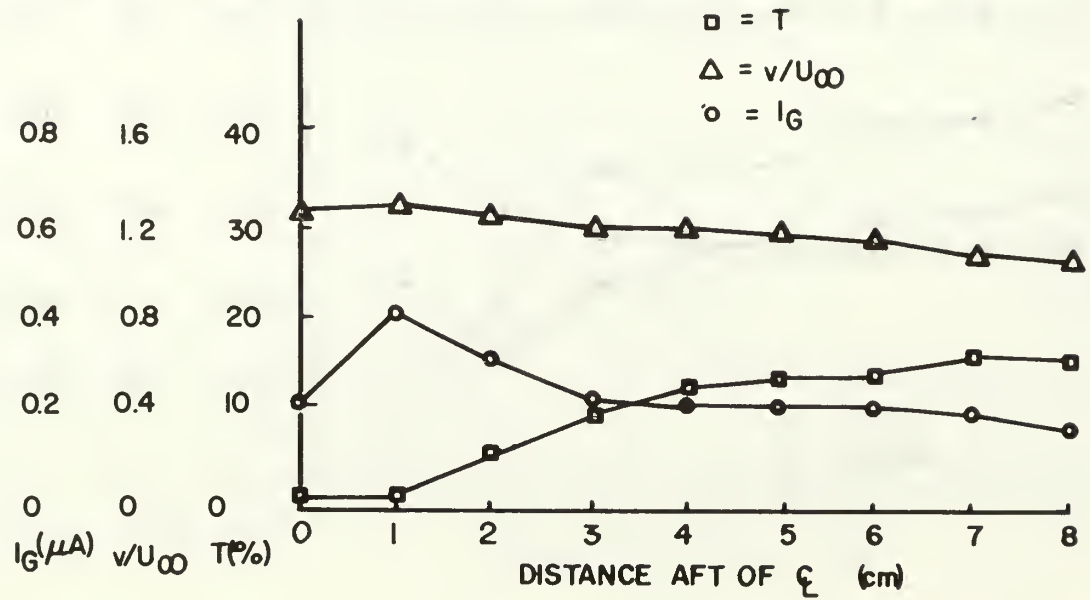


FIGURE 13. VELOCITY, TURBULENCE AND COLLECTOR CURRENT (TWO CM. TO RIGHT OF CENTERLINE)

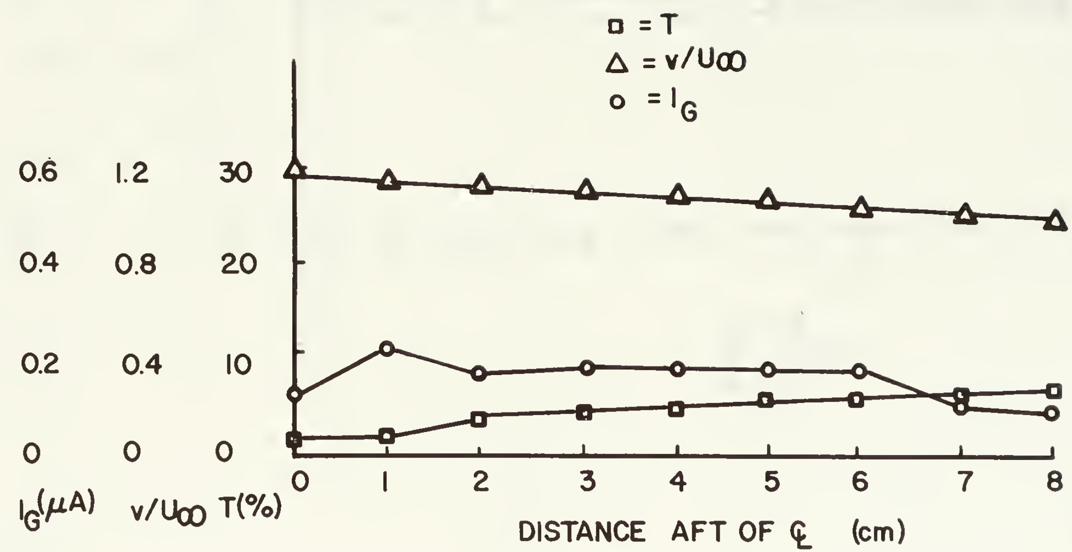


FIGURE 14. VELOCITY, TURBULENCE AND COLLECTOR CURRENT (THREE CM. TO RIGHT OF CENTERLINE)

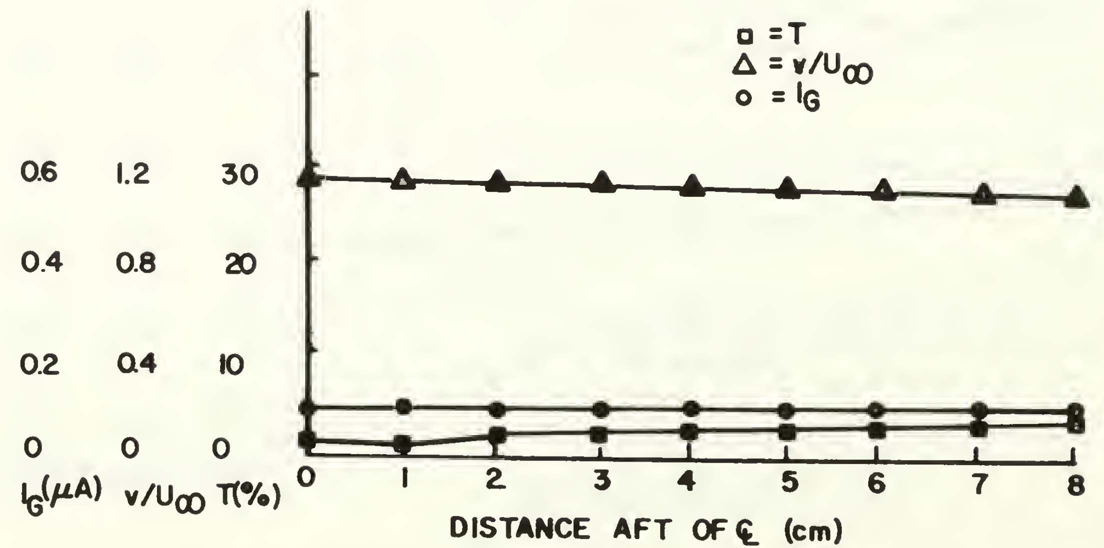


FIGURE 15. VELOCITY, TURBULENCE AND COLLECTOR CURRENT (FOUR CM. TO RIGHT OF CENTERLINE)

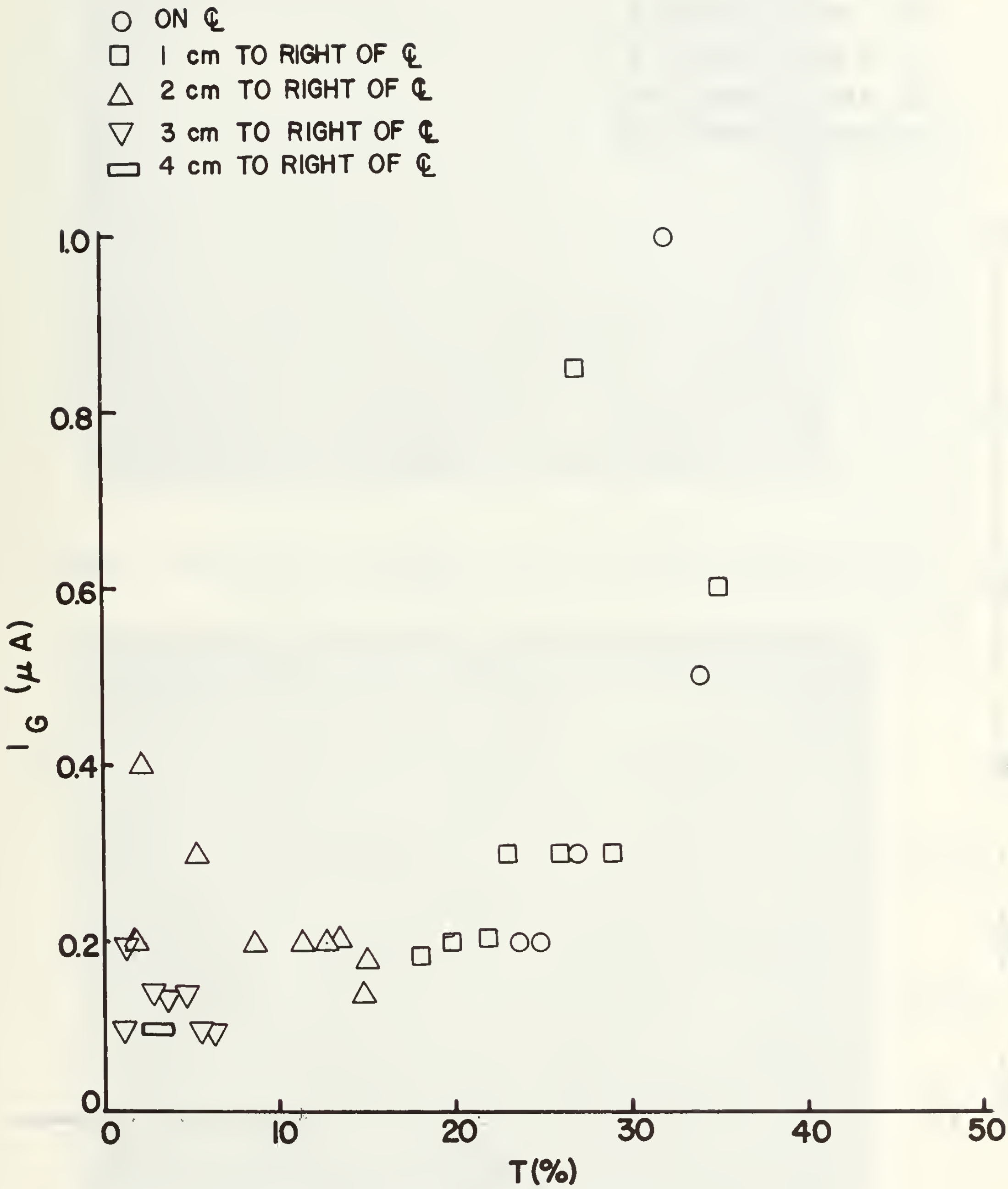


FIGURE 16. SCATTERGRAM OF COLLECTOR CURRENT AND TURBULENCE

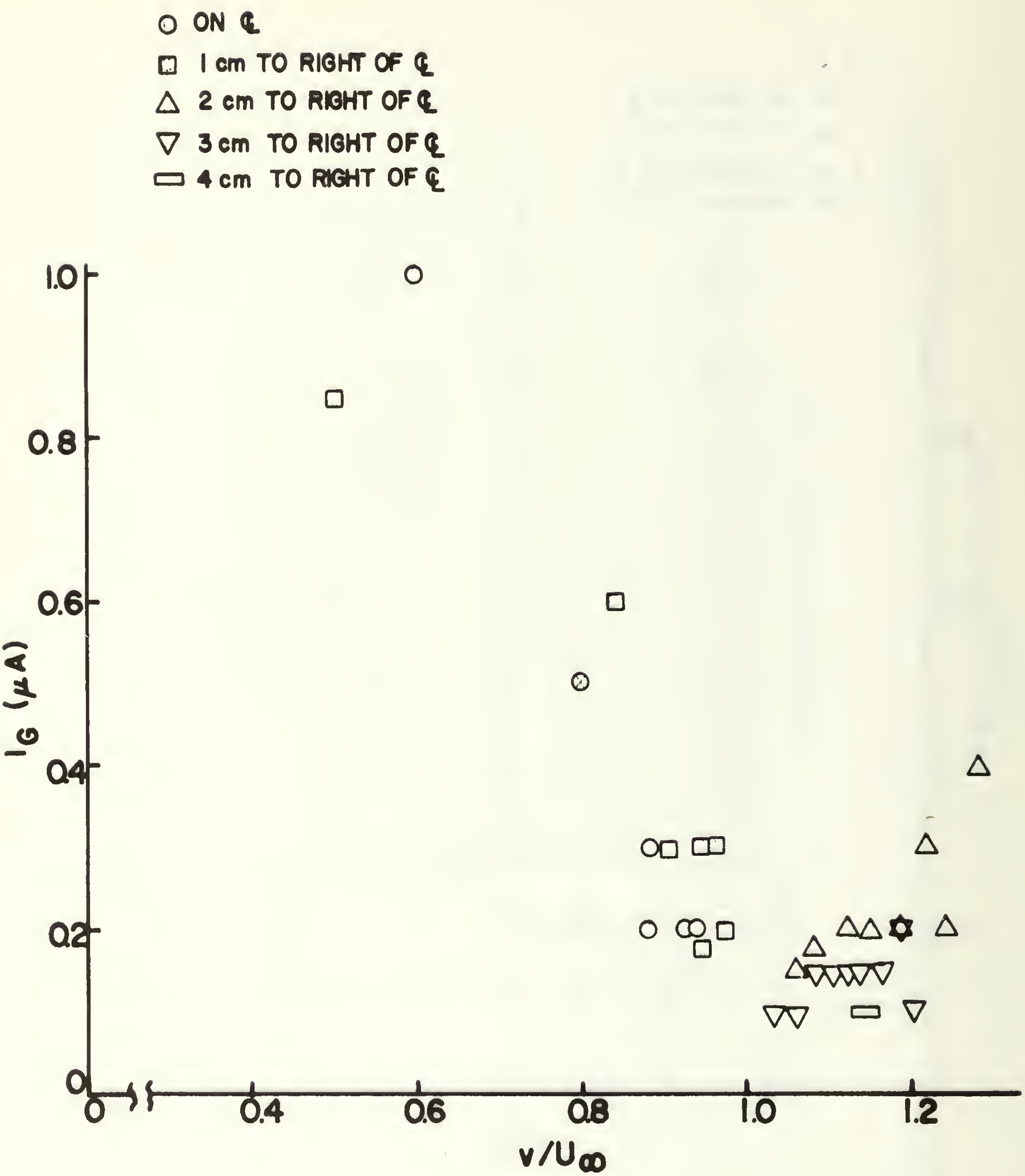
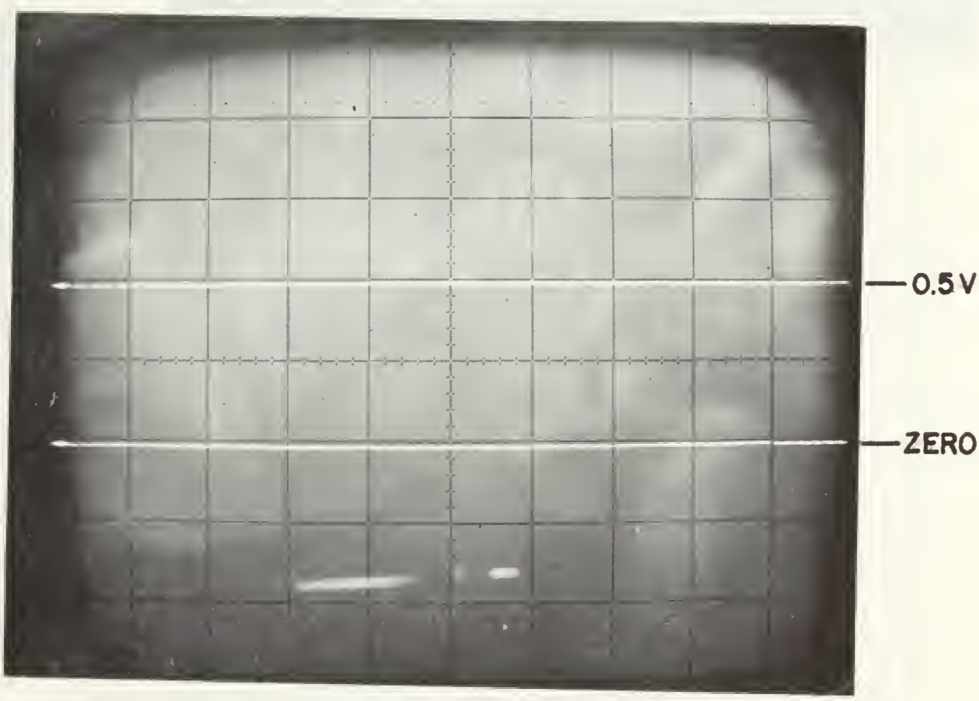


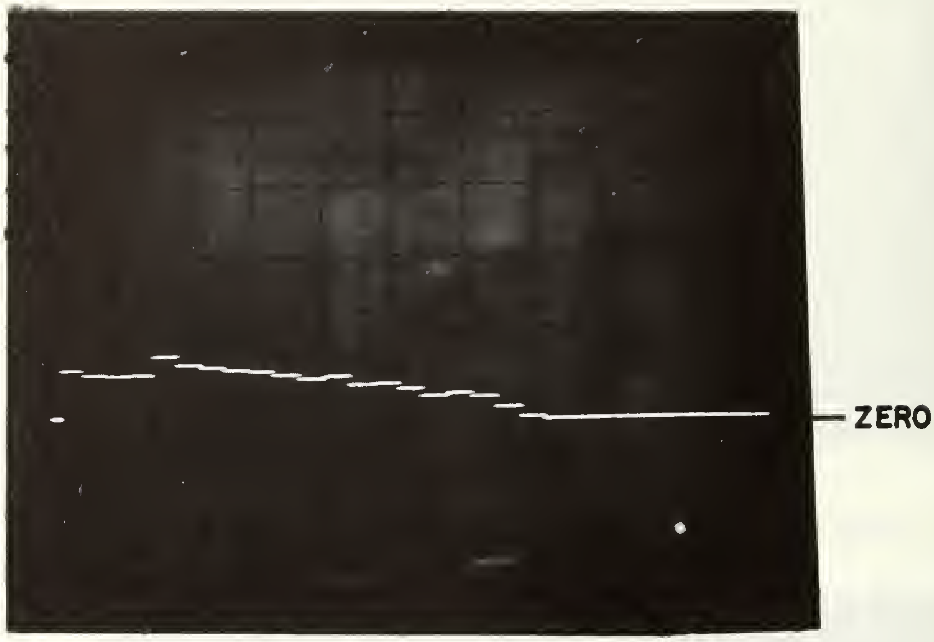
FIGURE 17. SCATTERGRAM OF COLLECTOR CURRENT AND MEAN VELOCITY

FREE STREAM REFERENCE FROM HOT-WIRE ANEMOMETER



INTERNAL CALIBRATION (0.5V)

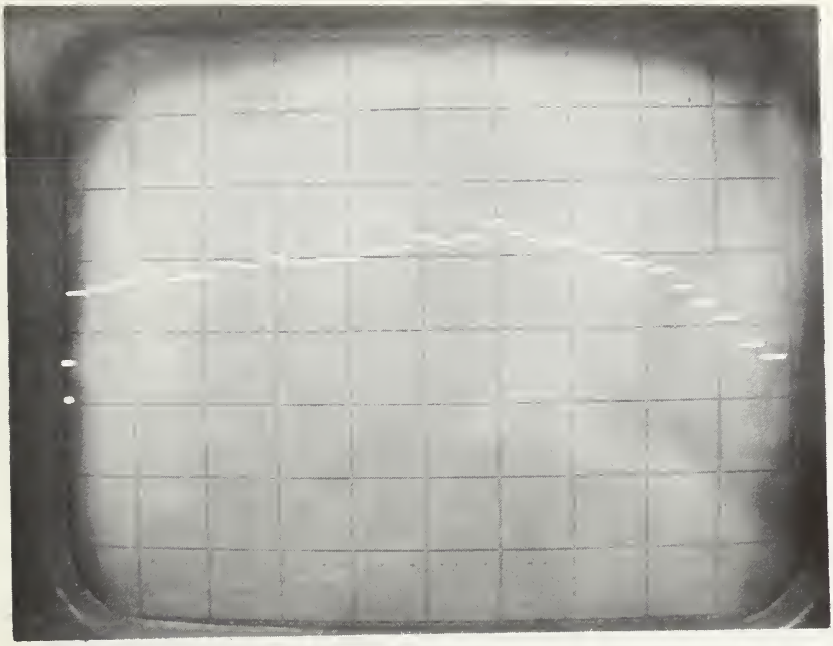
FIGURE 18. X-Y DISPLAY



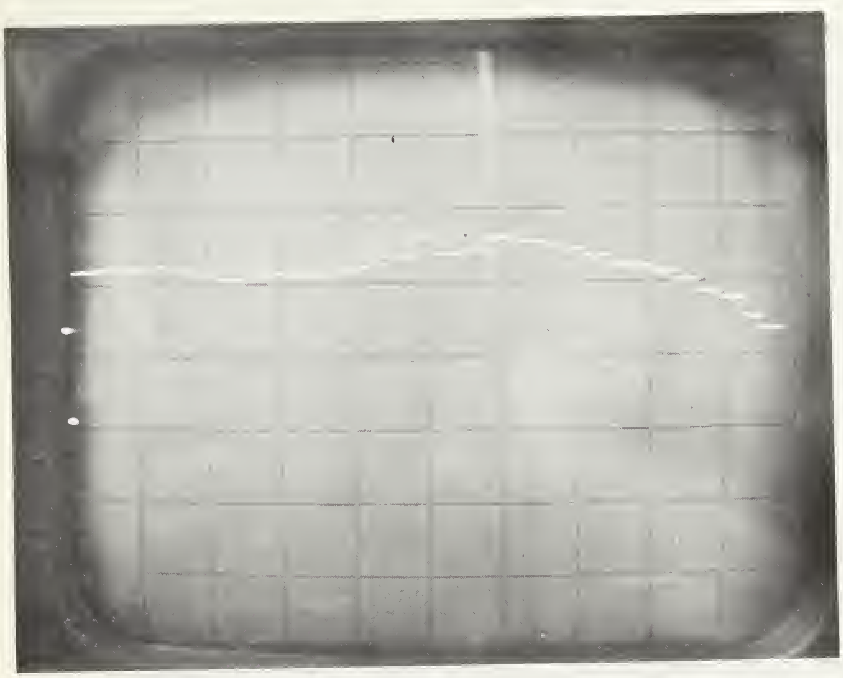
REFERENCE FOR STEAM ONLY

L = 3mm (℄) , $I_G = 0.1 \mu A$

FIGURE 19. X-Y DISPLAY FROM EGD PROBE



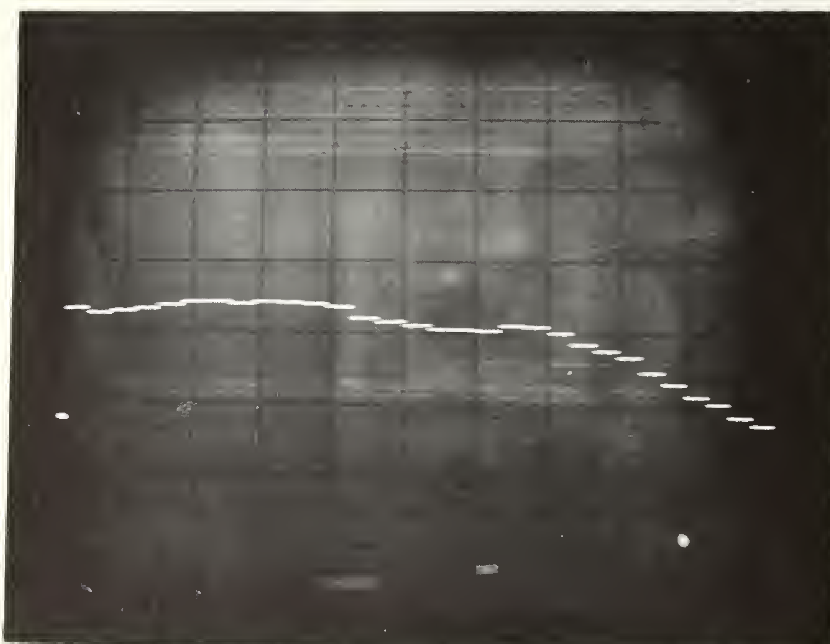
MAIN AIR ONLY (185 ft/s), (v/U_∞ = 0.6)



MAIN AIR (185 ft/s), (v/U_∞ = .6), NOZZLE AIR (13 PSIG)

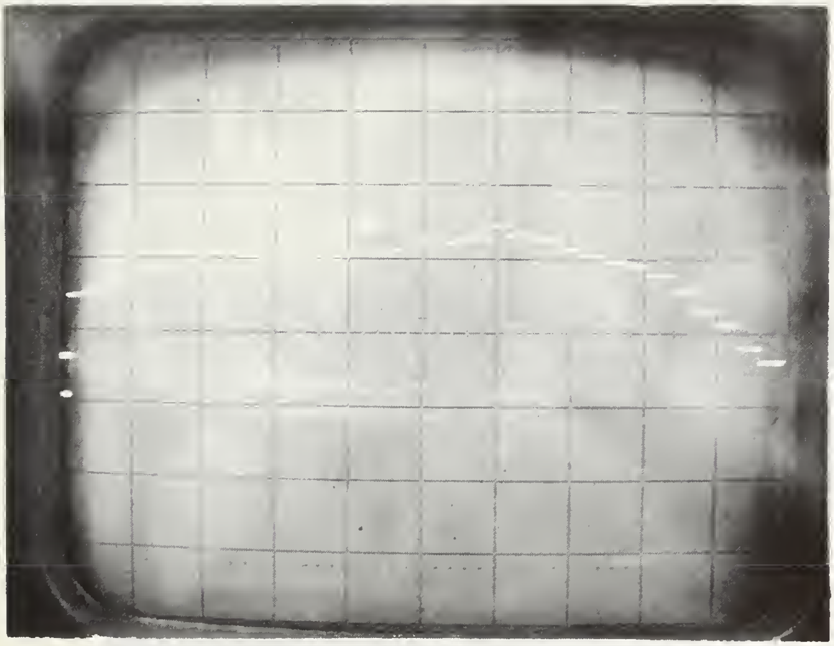
FIGURE 20. X-Y DISPLAY FROM HOT-WIRE ANEMOMETER
L = 4 mm (℄)

I_G = 0.3μA, MAIN AIR (185 ft/s), STEAM (14 PSIG)
4 SECOND INTEGRATION TIME



I_G = 0.3 A, MAIN AIR (185 ft/s), STEAM (14 PSIG)
8 SECOND INTEGRATION TIME

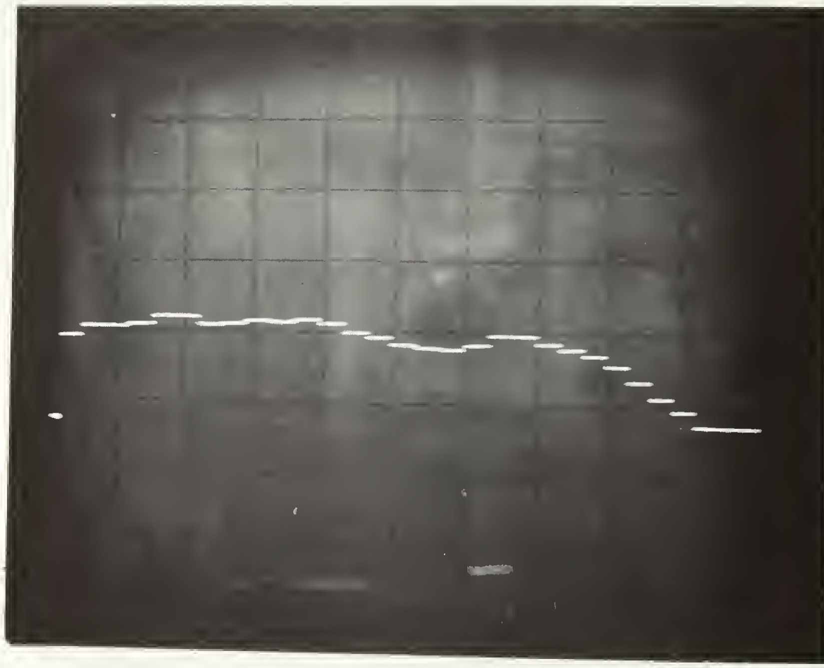
FIGURE 21. X-Y DISPLAY FROM EGD PROBE—L = 4mm (℄)



MAIN AIR ONLY (185 ft/s), (v/U_∞ = .6)

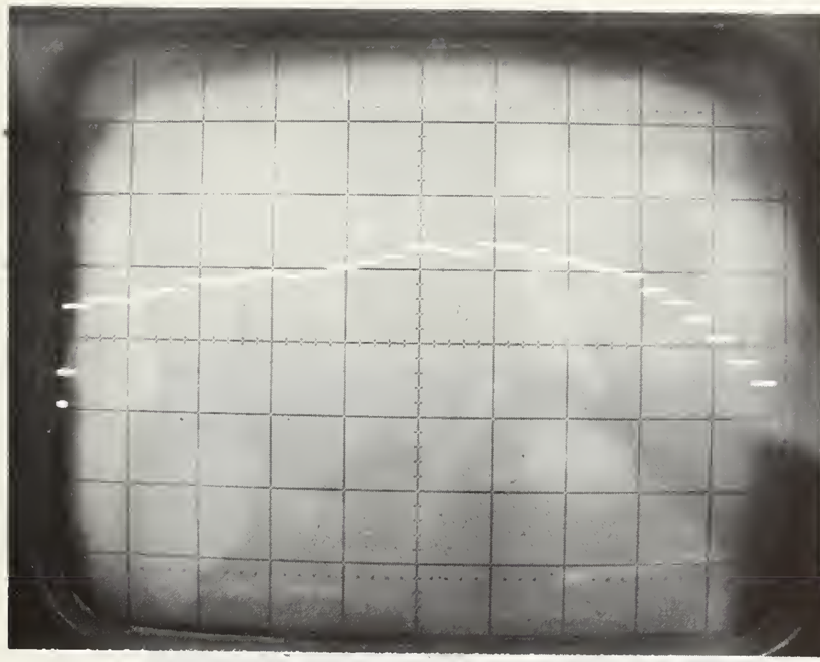
MAIN AIR (185 ft/s), (v/U_∞=.84), NOZZLE AIR (13 PSIG)

FIGURE 22. X-Y DISPLAY FROM HOT-WIRE ANEMOMETER
L = 5 mm (℄)

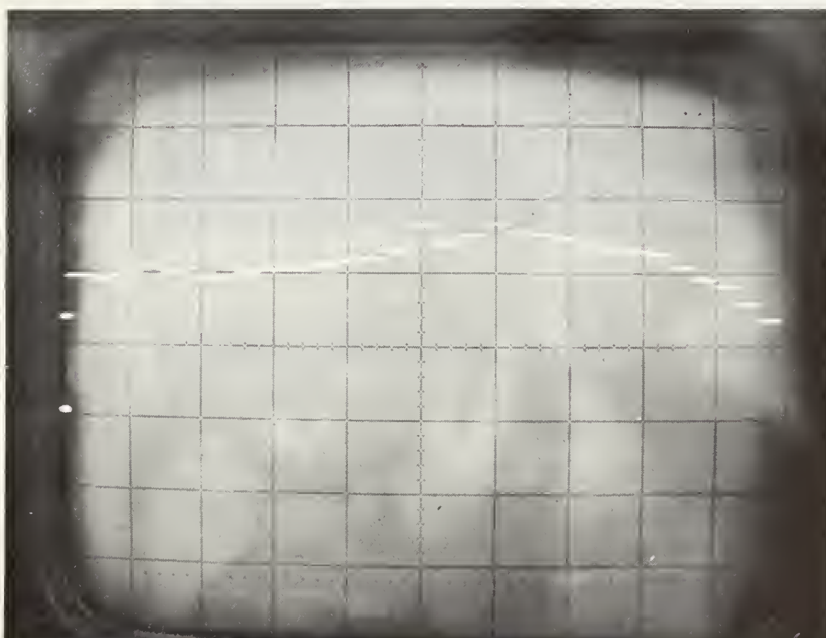


I_G = 0.2μA, MAIN AIR (185 ft/s), STEAM (14 PSIG)

FIGURE 23. X-Y DISPLAY FROM EGD PROBE
L = 5mm (℄)



MAIN AIR ONLY (185 ft/s), (v/U_{∞} = .54)

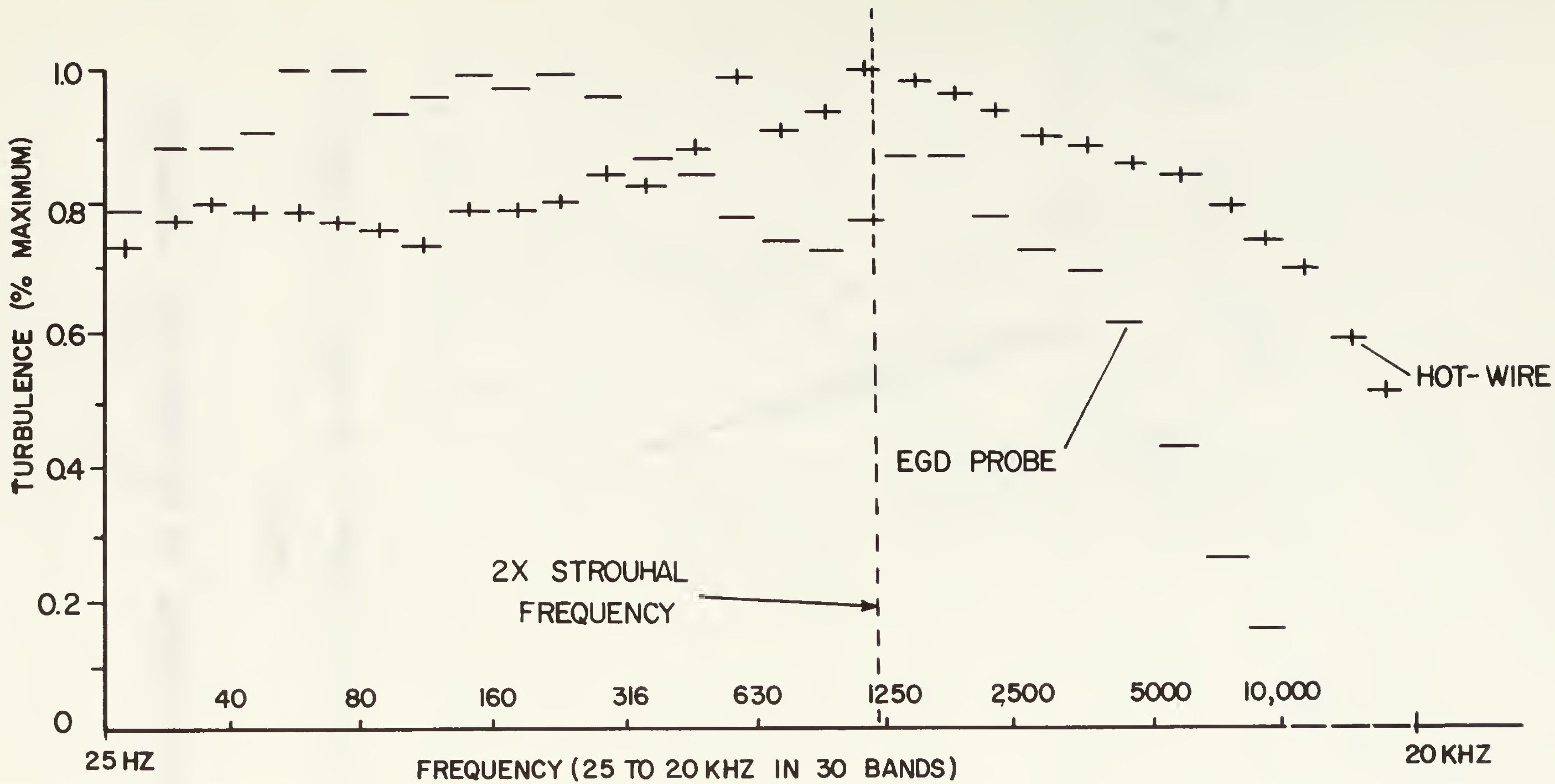


MAIN AIR (185 ft/s, (v/U_{∞} = 1.14), NOZZLE AIR (15 PSIG)

FIGURE 24. X-Y DISPLAY FROM HOT WIRE ANEMOMETER
L = 7 mm (℄)

MAIN AIR (185 ft/s), $I_G = 0.2 \mu A$, STEAM (14 PSIG)

FIGURE 25. X Y DISPLAY FROM EGD PROBE
L = 7 mm (℄)



HOT WIRE: MAIN AIR (185 ft/s, (v/U_{∞} = .84), NOZZLE AIR (13PSIG)

EGD PROBE: $I_G = 0.2\,\mu A$, MAIN AIR (185 ft/s), STEAM (14 PSIG)

FIGURE 26. NORMALIZED X-Y DISPLAYS — L = 5 mm (℄)

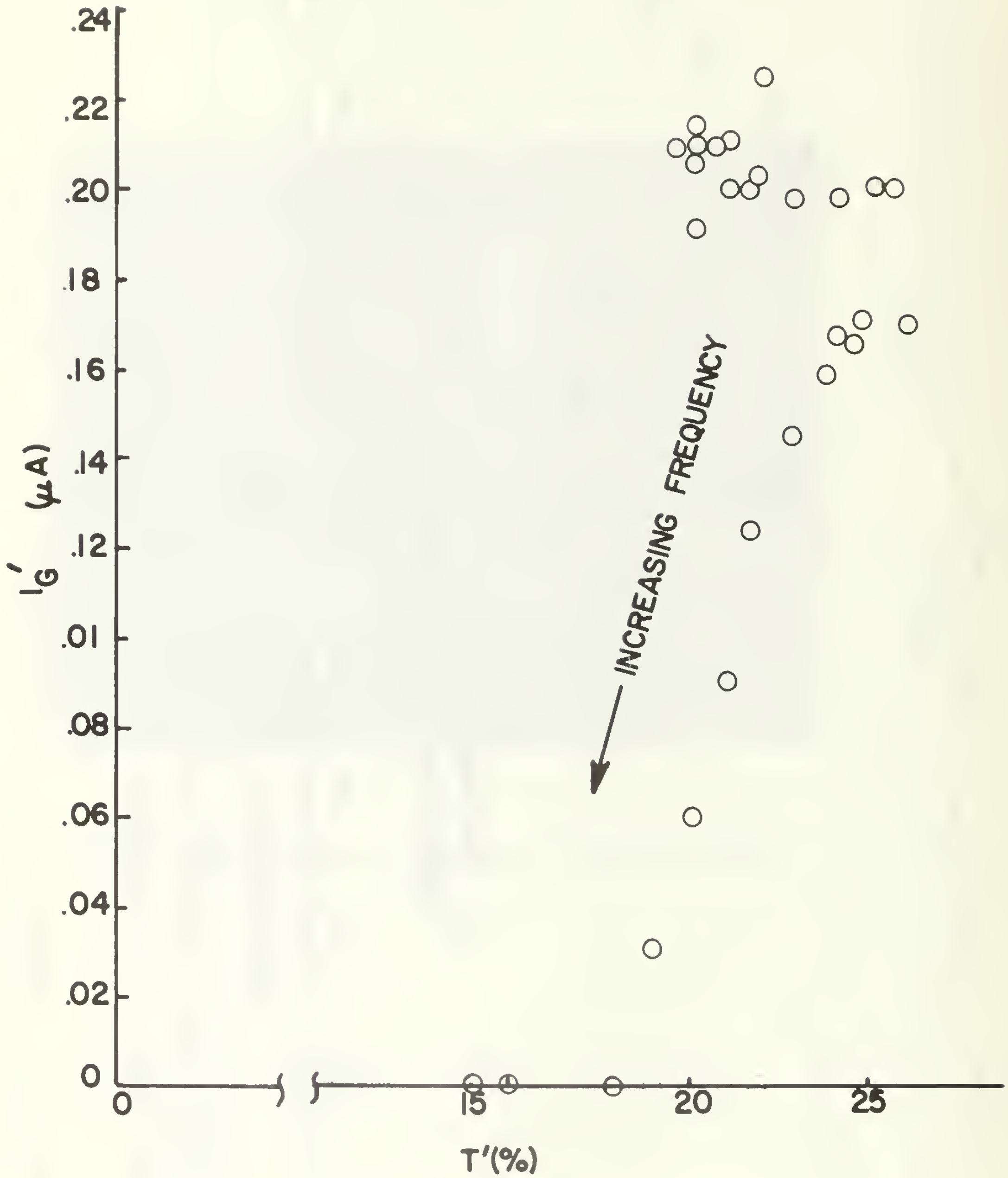


FIGURE 27. SCATTERGRAM OF X-Y DISPLAYS, L = 5mm (℄)

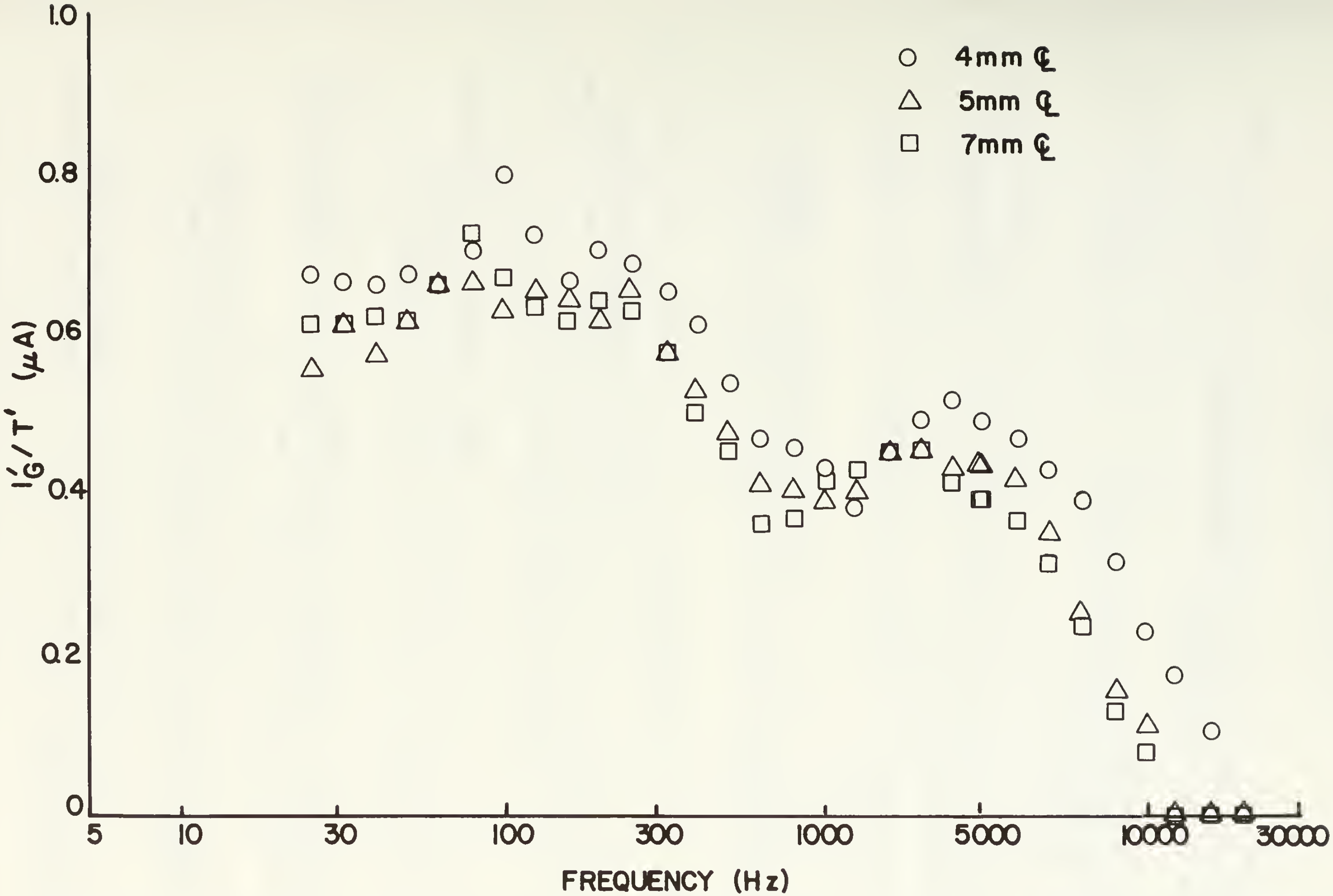


FIGURE 28. FREQUENCY DEPENDENCE OF THE RATIO OF COLLECTOR CURRENT TO TURBULENCE

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ABSTRACT

This study involves the investigation of the feasibility of an electrogasdynamic (EGD) probe to measure mean and turbulent velocities. The free stream velocity was 185 ft/sec and measurements were made in the wake of a circular cylinder 2 cm in diameter. Readings made with a hot-wire anemometer at the same location and in the same spectral range were used as the standard of comparison.

The initial data indicated that investigations should be restricted to the region from 2 mm to 10 mm aft of the injector nozzle along the center line. Spectral data for both the hot-wire and the EGD probe measurements were obtained with a frequency analyzer and photographed from an X-Y display.

The use of an EGD probe for measurements of mean and rms velocities may be feasible since the results indicate a definite correlation. The utility of the probe, however, is yet to be demonstrated since both the spatial and spectral comparisons with the hot-wire results show some lack of correspondence. The EGD unit proved to be considerably more rugged than the hot-wire probe.

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Investigation of the feasibility of an electrogasdynamic probe for measurements of mean and RMS velocities.